

## **I. EXECUTIVE SUMMARY**

### **Background**

There is a growing literature reporting traffic exposure impacts on respiratory health in children. Very few studies in the U.S. have used advanced Geographic Information System (GIS) modeling techniques, such as land use regression (LUR), to estimate exposures on a fine spatial scale. LUR models based on intensive neighborhood monitoring of traffic pollutants have not been developed for the Los Angeles (LA) Basin in Southern California, one of most polluted regions in the U.S. There is currently a lack of neighborhood-level air pollution measurements for Californian children that live in high traffic density areas and who may be more susceptible to adverse health impacts from air pollution exposure due to economic disadvantage. Thus, the objectives of this research were to: (1) to conduct  $\text{NO}_x$  and  $\text{NO}_2$  monitoring at 200 locations within LA County neighborhoods with varying levels of economic disadvantage and varying exposures to air pollution originating from vehicular sources; (2) to use these monitoring data to help inform LUR models for predicting traffic pollutant exposures (i.e.,  $\text{NO}_x$ , NO and  $\text{NO}_2$ ); (3) to use geostatistical models to estimate regional background concentrations of  $\text{O}_3$  and  $\text{PM}_{2.5}$ ; (4) to evaluate associations between exposure to  $\text{NO}_x$ , NO and  $\text{NO}_2$  and measures of respiratory health and lung function in children in conjunction with the Los Angeles Family and Neighborhood Survey (L.A. FANS) study; and (5) to evaluate whether concentrations of the more regionally distributed background pollutants ( $\text{O}_3$  and  $\text{PM}_{2.5}$ ) confound or modify the effects of exposure to the more heterogeneously distributed traffic-related pollutants ( $\text{NO}_x$ , NO and  $\text{NO}_2$ ).

### **Methods**

We developed land use regression (LUR) models to estimate long-term exposure to traffic air pollution for 1,387 children who participated in the Los Angeles Family and Neighborhood Wave Two Survey (L.A. FANS-2) and examined associations with cross-sectional measures of respiratory symptoms and lung function while adjusting for many different family- and neighborhood-level socioeconomic characteristics assessed as part of L.A. FANS-2. First, a campaign of  $\text{NO}_x$  and  $\text{NO}_2$  monitoring using passive badges was conducted throughout 65 L.A. FANS neighborhoods (census tracts). Nitrogen oxides ( $\text{NO}_x$ ), nitric oxide (NO) and nitrogen dioxide ( $\text{NO}_2$ ) were selected as markers of motor vehicle exhaust exposure for this study since they are relatively easy to measure (both from a logistics and cost standpoint), which allowed us to conduct simultaneous measurements at a large number of locations throughout L.A. County. Existing data indicate these pollutants serve as a good marker for localized traffic pollution and are associated with asthma prevalence and symptoms.<sup>1-5</sup> Two-week measurements were collected during two time periods selected to best represent an annual average. These data were then used to build LUR prediction surfaces for NO,  $\text{NO}_2$  and  $\text{NO}_x$  on a 25 x 25 meter grid over the L.A. Basin. Geocoded L.A. FANS-2 residential and school locations were overlaid with the exposure surfaces and NO,  $\text{NO}_2$  and  $\text{NO}_x$  annual average estimates extracted for each location. Extracted annual averages were weighted by time spent at each home and school within various time periods to generate final exposure metrics (current home, 1-year, 2-years, 5-years prior to interview). Exposure surfaces for  $\text{O}_3$  and  $\text{PM}_{2.5}$  were also generated by kriging available government monitoring data for the years 2002 and 2000, respectively. Similar to the LUR metrics, final annual average  $\text{O}_3$  and  $\text{PM}_{2.5}$  exposure metrics were then created, weighting for time spent at home(s) and school(s). Multivariate logistic regression was used to evaluate associations between LUR and kriged air pollution estimates and odds of: doctor-diagnosed asthma (ever); wheeze, wheeze with any night waking, medication use for asthma or wheeze,

and sneezing or a runny or blocked nose apart from colds in the past 12 months, and more than 3 doctor-diagnosed ear infections in a year. Multivariate linear regression was used to estimate changes in lung function as assessed via EasyOne™ portable spirometers with increasing air pollution exposure. The specific lung function parameters evaluated were: peak expiratory flow rate (PEF), forced vital capacity (FVC), forced expiratory volume after 1 second (FEV<sub>1</sub>), forced expiratory mean flow between 25% and 75% of FVC (FEF<sub>25-75</sub>), and forced expiratory mean flow at 75% of FVC (FEF<sub>75</sub>).

## Results

Final LUR models for the L.A. Basin explained 81%, 86% and 85% of the variation in NO, NO<sub>2</sub> and NO<sub>x</sub> concentrations, respectively. Novel aspects of the LUR modeling effort include: (1) the use of a large number of sampling sites (~200) for simultaneous passive measurement of NO, NO<sub>2</sub> and NO<sub>x</sub> over a large and complex geographic region, (2) use of “A Distance Decay REgression Selection Strategy” (ADDRESS)<sup>6</sup> to explore importance of geographic features within many different size buffers and develop spatial models highly predictive of measured concentrations, and (3) use of remote sensing data to provide additional information on geographic distribution of traffic sources and improve LUR model predictions. LUR model results indicated traffic on highways and major roads as far away as 11 km from measurement sites still had important impacts on measured NO<sub>x</sub> concentrations, a much greater spatial extent than previously reported in the literature.<sup>7</sup> Although incorporating the influence of traffic at farther distances improved prediction ability for NO, NO<sub>2</sub> and NO<sub>x</sub>, we generated a separate set of LUR models that excluded traffic at distances greater than 5000 m (resulting R<sup>2</sup> values were 0.64, 0.78 and 0.68, respectively), as concentrations of ultrafine particles have been shown to reach background concentration within closer proximity to roadways in LA.<sup>8-13</sup> Thus, LUR models excluding traffic at greater distances may provide better surrogate estimates of exposure for fresh vehicle exhaust and UF and associated toxics that are also of biologic interest for respiratory health (even though they were less predictive for NO, NO<sub>2</sub> and NO<sub>x</sub>).

Children more highly exposed to traffic pollution as estimated by interquartile (IQR) increases in the “more local traffic” LUR model estimates for NO (11.8 ppb), NO<sub>2</sub> (6.1 ppb) and NO<sub>x</sub> (16.9 ppb) were approximately 30-40% more likely to report wheeze in the past 12 months (current wheeze). These estimates were robust to adjustment for many different family- and neighborhood-level socioeconomic factors. We observed weaker and more marginal 15% increases in odds of medication use for asthma and wheeze in the past year and doctor-diagnosed asthma per IQR increase in NO, NO<sub>2</sub> and NO<sub>x</sub>. However, when we stratified analyses by median census tract-level economic disadvantage, odds for both asthma outcomes in higher but not lower SES areas were found to increase by approximately 40% per IQR increase in traffic pollution. This may, in part, reflect differential access to health care and resulting differences in asthma diagnosis and reporting in higher versus lower SES communities. However, in lower SES areas only, we estimated 80-100% increases in odds of current wheeze and medication use for asthma and wheeze per IQR increase in peak 8-hour O<sub>3</sub>, while null or inverse associations between peak O<sub>3</sub> and these outcomes were observed for children living in higher SES areas. These results may in part reflect differences in children’s behaviors (e.g., time spent outdoors in summer) and resulting exposures in lower versus higher SES communities during high O<sub>3</sub> pollution episodes. However, these findings are based on a relatively small sample size in each SES stratum.

Similar to previous cross-sectional studies in Europe and the U.S., we observed reductions in lung function with increasing exposure to traffic pollution, but our results differed

substantially between girls and boys and varied between children with lower and higher quality spirometry curves. In boys, we estimated 70-100 mL reductions in lung volume and 60-100 mL/s decrements in expiratory flow per IQR increases in LUR estimates of NO, NO<sub>2</sub>, and NO<sub>x</sub>. Slightly lower associations were observed for PM<sub>2.5</sub> exposures (40-50 mL reductions in volume and 60-90 mL/s reductions in flow per IQR increase). However, when restricting analyses to boys with three acceptable and reproducible curves, negative associations were more imprecisely estimated and in general did not reach statistical significance, except for those between PM<sub>2.5</sub> and FEF<sub>75</sub> and FEF<sub>25-75</sub>. In girls, we estimated 40-80 mL reductions in FEV<sub>1</sub> with increasing exposure to LUR-estimates of NO, NO<sub>2</sub> and NO<sub>x</sub>, but no associations with FVC. However, much greater associations between traffic pollution and measures of expiratory flow were observed in girls versus boys (300-350 mL/s reductions in PEF and 200-300 mL/s reductions in FEF<sub>25-75</sub> per IQR increase in NO, NO<sub>2</sub> and NO<sub>x</sub>). However, these results were not replicated in the group of girls with three acceptable and reproducible curves. This may be due to the smaller sample size and/or the characteristics of the select group for which we had three reproducible curves available (i.e., girls of higher SES and with higher exposure to O<sub>3</sub> and lower exposure to traffic pollutants). Similar to previous U.S. cross-sectional studies,<sup>14-16</sup> we also observed reductions in PEF in girls more highly exposed to peak daily O<sub>3</sub> (~100 mL/s decrement and ~400 mL/s decrement per 30 ppb increase in O<sub>3</sub> for girls with one or more acceptable curves and three acceptable and reproducible curves, respectively).

## Conclusions

L.A. FANS-2 children more highly exposed to traffic pollution were more likely reported as having current wheeze symptoms (66% of children with current wheeze were also reported as having a doctor-diagnosis of asthma, 34% did not). We also observed positive associations between LUR traffic exposure metrics and odds of doctor-diagnosed asthma and medication use for asthma and wheeze in the past year, although these associations were not as strong as those estimated for current wheeze. Differences in access to health care and physician practices for diagnosing asthma across communities may be factors affecting our results for these outcomes. This conclusion was supported by analyses in which we stratified on census-tract level economic disadvantage: in higher but not lower SES areas, we observed associations between LUR-estimated traffic exposures and odds of both asthma outcomes similar in magnitude to those observed for current wheeze. Relatively strong associations between exposure to peak daily O<sub>3</sub> and current wheeze and medication use for asthma and wheeze were observed in lower SES areas, while no or inverse associations were observed in higher SES areas, which may reflect differences in children's time-activity patterns and resulting exposures across communities during high O<sub>3</sub> pollution episodes. We observed reductions in lung function with increasing exposure to traffic pollution, but our results differed substantially between girls and boys and were not consistent for children with poorer versus better quality spirometry curves. Decrements in lung volumes and flows with increasing exposure to traffic pollution were observed in boys, but when restricting to subjects with higher quality spirometry curves (three acceptable and reproducible curves), results were imprecise and associations did not reach statistical significance, except for those between PM<sub>2.5</sub> and FEF<sub>75</sub> and FEF<sub>25-75</sub>. For girls, much stronger associations were observed between LUR-estimates of traffic exposure and expiratory flows (PEF and FEF<sub>25-75</sub>) than for boys, however these traffic effects were not replicated in the smaller and select sub-group of girls with three acceptable and reproducible curves. Girls who were more highly exposed to peak daily O<sub>3</sub> had substantially lower measures of PEF. Similar to previous

studies, our results suggest important differences in the biological impact of air pollution on lung health in boys versus girls.

## II. INTRODUCTION

### Scope and Purpose

A large literature links outdoor air pollution exposure to adverse respiratory health effects in children and adults.<sup>17-21</sup> Recently, air pollution research has focused on the contributions of specific motor vehicle exhaust components such as polycyclic aromatic hydrocarbons (PAHs) adsorbed to particles from diesel engines and ultrafine particles (less than 0.1  $\mu\text{m}$  in aerodynamic diameter), which are more able to penetrate cellular targets in the lung and enter systemic circulation.<sup>1,22-24</sup> Various measures of traffic exhaust exposure have been associated with adverse respiratory outcomes including reduced lung function and growth, asthma hospitalizations, and prevalence of asthma, wheeze, bronchitis, and allergic rhinitis.<sup>4,25-27</sup> Many of the studies linking pollutants originating from traffic to poorer respiratory health have relied on surrogate exposure measures such as proximity to and extent of traffic on roadways near residences and schools. A relatively new approach for predicting outdoor traffic pollutant concentrations is land use regression (LUR) modeling. Land-use regression utilizes measured levels of the pollutant of interest as the dependent variable and traffic, topographic, and other geographic variables as independent predictor variables in a multivariate regression model.<sup>28,29</sup> The incorporation of site-specific variables in this method detects small area variations of traffic related pollution more effectively than other methods of geostatistical interpolation.<sup>28-30</sup>

European studies associated levels of  $\text{PM}_{2.5}$ , soot, and  $\text{NO}_2$  assessed via LUR modeling with the development of adverse respiratory symptoms such as wheezing early in life.<sup>26,31,32</sup> LUR-based estimates of  $\text{PM}_{2.5}$  were also associated with an increase in exhaled NO (a marker of lung inflammation) and reduced forced vital capacity in Canadian schoolchildren.<sup>33</sup> Overall, there have been very few studies in the U.S. using LUR exposure metrics to examine traffic impacts on respiratory health in children, and no such study has been conducted in the Los Angeles (LA) Basin in Southern California, one of most polluted regions in the U.S. where traffic is a major source of air pollution. Currently, neighborhood level air pollution measurements for Californian children that live in high traffic density areas are lacking and these children may also be more susceptible to adverse health impacts from such exposures due to economic disadvantage. Gunier et al.<sup>34</sup> recently reported that low-income children and children of color in California are more likely to live in census block groups with high traffic density and concluded that future studies should target these high density traffic areas and evaluate differences in health risks by income and race/ethnicity.

Thus, the objectives of this research were to: (1) to conduct  $\text{NO}_x$  and  $\text{NO}_2$  monitoring at 200 locations within LA County neighborhoods with varying levels of economic disadvantage and varying exposures to air pollution originating from vehicular sources; (2) to use these monitoring data to help inform land use-based regression (LUR) models developed to predict traffic pollutant – i.e.,  $\text{NO}_x$ , NO and  $\text{NO}_2$  – exposures; (3) to use geostatistical models to estimate regional background concentrations of  $\text{O}_3$  and  $\text{PM}_{2.5}$ ; (4) to evaluate associations between exposure to  $\text{NO}_x$ , NO and  $\text{NO}_2$  (as estimated by the developed LUR models) and measures of respiratory health and lung function in children in conjunction with the Los Angeles Family and Neighborhood Survey (L.A. FANS) study;<sup>35</sup> and (5) to evaluate whether concentrations of the more regionally distributed background pollutants ( $\text{O}_3$  and  $\text{PM}_{2.5}$ ) confound or modify the effects of exposure to the more heterogeneously distributed traffic-related pollutants ( $\text{NO}_x$ , NO and  $\text{NO}_2$ ).